Implementing Strategic Management of Producibility in Military Hardware Design

Randy S. Dawley

Central Michigan University

Advisor: Dr. Lawrence Zeff

Monitor: Dr. Hal W. Stephenson

Course: MSA-685

May 1985

7414 Hartel
Westland, MI 48185
July 2, 1985

Defense Technical Information Center (DTIC)
Bldg. 5, Cameron Station
Alexandria, VA 22304-6145

Enclosed is two copies of my Master's Thesis titled "Implementing Strategic Management of Producibility in Military Hardware Design", and a copy of the release from my corporation for the material, which is unclassified and unlimited.

I would like to have the document entered into your database. Please advise me of your decision.

I would suggest some key words: producibility, productivity, design, drawing requirements, design to cost, and PEP.

Sincerely yours,

Randy S Dawley

Randy S. Dawley, P.E.

Telephone:
Home (313) 422-7234
Bus. (313) 497-7414

GENERAL DYNAMICS
Land Systems Division

REQUEST FOR RELEASE APPROVAL

Log No. ____________

OF TECHNICAL ARTICLE, PAPER OR SPEECH TO BE PRESENTED OR PUBLISHED

Submit 4 copies of Clearance Request and 2 copies of speech or paper. These will be returned.

DATE June 14, 1985

AUTHOR Randy S. Dawley — 8331 — 954-7414
NAME - PLEASE PRINT — DEPT NO. — PHONE

☐ ABSTRACT ☒ FINAL PAPER ☐ SCRIPT

1. TITLE OF ARTICLE/PAPER Implementing Strategic Management of Producibility in Military Hardware Design

2. FOR PRESENTATION TO Defense Technical Information Center (DTIC), with excerpts to Army RD&A Magazine (or equivalent).
NAME OF JOURNAL OR SOCIETY

PLACE ____________ DATE After Release

3. Is any of the information taken from Government contract material? ☒ NO ☐ YES State CONTRACT NO. ____________

4. I believe this material to be ☒ UNCLASSIFIED and Unlimited ☐ CONFIDENTIAL ☐ SECRET

AUTHOR'S SIGNATURE R S Dawley

5. APPROVED BY:

A. MANAGER who verifies (1) Classification; (2) Professional Quality; (3) Protection of Land Systems Division Policy and Proprietary Interest.

JRlotter 6-18-85 — Manager — Quality Assurance
SIGNATURE — TITLE — DEPT. FUNCTION

B. (1) ENGINEERING ADMINISTRATION: Received M. Curran 6/19/85

(2) LEGAL DEPARTMENT: Patent Questions ☐ ARE INVOLVED ☒ ARE NOT INVOLVED

E. J. Stieber — 6/19/85
SIGNATURE — DATE

(3) INDUSTRIAL SECURITY: Material is ☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET

Department of Defense Approval is ☒ NOT REQUIRED ☐ REQUIRED

Full address of Dept. of Defense Approving Agency: ____________

Richard E. — JUN 1 9 1985
SECURITY OFFICER - SIGNATURE — DATE

(4) CONTRACTS & ESTIMATING: JRCasser — 6/21/85
DIRECTOR - SIGNATURE — DATE

6. APPROVAL FOR RELEASE:

PUBLIC AFFAIRS OFFICE - MATERIAL IS ☒ RELEASABLE ☐ NOT RELEASABLE

D S Norman — 6/26/85
SIGNATURE — DATE

7. COMMENTS (Initial to indicate by whom made) ____________

84-013-0836 (10-84)

Implementing Strategic Management of Producibility in Military Hardware Design

Randy S. Dawley

Central Michigan University

Advisor: Dr. Lawrence Zeff

Monitor: Dr. Hal W. Stephenson

Course: MSA-685

May 1985

Abstract

The balance between functional design requirements and manufacturing capabilities in the design and production of military hardware must be established during the early stages of design development to maximize cost efficiency of the total system and to establish a foundation of preparedness in the event of industrial mobilization. This writing reveals how such a balance has been obtained historically, and presents a strategy for developing production ready designs. The discipline that assures an optimal balance of performance at minimal cost and delivery time is producibility. The characteristics that allow production personnel to readily build to a design are not automatically inherent in the design, but rather must be required of the design agency by high levels of authority. The findings indicate creation of a synergistic effect through design teams composed of both design and manufacturing personnel. Two new acronyms are presented. 1. PRAM-D, Producibility, Reliability, Availability, Maintainability and Durability. 2. DPEP, Design Producibility Engineering and Planning, which is synonymous with producibility measures. The benefits of a fully implemented producibility program are optimal cost, schedule, and quality.

ACKNOWLEDGEMENTS

Sincere appreciation is extended to those who have impacted the development of this study. Special appreciation is extended to Dr. Hal W. Stephenson for providing consultation and guidance throughout the study in the capacity of Project Monitor for the graduate committee.

Special thanks are extended to George J. Brigholin and Harry L. Hedblom for the roles they have had in formulating the writers thoughts, opinions, and philosophies on the subject of producibility.

TABLE OF CONTENTS

Chapter I

The inherent characteristics of modern military hardware designs provide the manufacturing community with greater challenges than ever before. Demanding performance specifications of modern equipment place an emphasis upon functional requirements that follow through directly to the constraints placed upon the manufacturer. A strategic plan must be developed and enforced from very high levels of authority to create an acquisition process that provides a formal means of design development whereby newly released designs have the necessary characteristics for efficient production.

Too often designs have arrived at production plants in a manner analogous to the early delivery of a load of cement. Although in the case of the cement a beneficial sense of urgency has been created, the lack of the necessary preparedness creates inefficiency and waste for the entire load of cement, or as in hardware, the entire production run. Preparedness here refers to the design engineering efforts at establishing drawing requirements suitable for production. The engineering drawing establishes a production foundation for productivity, efficiency, cost, labor, scheduling, and quality, which can be made no better than the engineering drawing permits. Product characteristics that establish the level of ease and economy

of manufacture have been termed producibility. The discipline of Producibility Engineering is composed of engineers with diverse manufacturing backgrounds that provide manufacturing input into engineering drawings as part of product design teams. In recognition of the need for a formalized plan for implementing a producibility program, this writing presents a strategy for managing producibility design control in military hardware development programs. The result is releases to manufacturing of designs that are inherently ready for efficient production in the quantities required.

Rationale and Background

The forerunner of today's engineering drawings consisted of pictures drawn to some scale which were used by single craftsman for building entire units or sub-units. There were no considerations regarding interchangeability or spare parts. As technology progressed and mass production techniques began, more details such as dimensions and tolerances were added to engineering drawings. Assembly problems created the job of fitter. Conflicts between dimensions and the picture were resolved by giving dimensions precedence. "Do not scale" warnings were marked on drawings. The rule became to provide dimensions just sufficient to define the geometry. One dimension more or one less, was and is still today, wrong. (Hillyard, 1978).

For any particular component part, there are numerous dimensioning and tolerancing schemes which provide the same component function. However, each scheme establishes and often dictates a specific set of manufacturing processes to satisfy the specified drawing requirements. The best technical design and the best design to manufacture do not coincide automatically, but require dedicated design efforts to reach that state as shown in figure 1. Producibility is

---

See Figure 1

---

concerned with establishing drawing requirements that will yield favorable conditions for manufacturing while maintaining the correct functional needs of the designer. The creation of engineering drawings must include producibility considerations to establish requirements suitable for efficient manufacturing.

Statement of Problem and Need

The significance and potential benefits of producibility design control became apparent during World War II. The industrial mobilization created the necessity to redesign particular hardware to reduce manufacturing problems and to enhance their ease of manufacture. The mobilization provided evidence of a lack of production readiness that necessitated untimely engineering changes or

complete redesigns. Prior to World War II, a designer's primary concern regarding production was that the products could indeed be manufactured. The level of effort required to produce a product has became a concern due to increased labor costs, increased sophistication of products, and technology advances in materials, manufacturing processes, and inspection techniques (DOD,1984,p.iii).

Formal producibility efforts can eliminate design requirements that require processing operations deemed unwarranted for product function that would otherwise have been applied to each component part produced over the life of the production run. An example of this type of excess cost is exemplified by dimensional constraints being placed upon a clearance hole that can only be obtained by a reaming or double drilling manufacturing process. Since this process is strictly a cost increase and can be readily accomplished by manufacturing, a design change after drawing release to eliminate the requirement is unlikely. This additional and unnecessary cost would continue for the production life of the item.

Establishing product part tolerances is one of the most important duties of the product design engineer. Excessive cost and production inefficiency can result from tolerances which are too tight or too loose. Tight tolerances create manufacturing and inspection problems while loose tolerances cause assembly and installation problems. The broad range of equipment and process capabilities that a designer must

have knowledge of makes necessary extensive education and experience. A management strategy combining the experienced designer with a producibility engineer will provide motivation for reducing the designer's tendency to specify unnecessarily tight tolerances, which is a long standing problem in the design system. John M. Leamen (1983,p.51), has shown that the tendency to over tolerance is due to:

1. Engineering education cultivates a tendency towards precision.

2. Tight tolerances are specified due to fears of interference or excessive clearance between mating parts. Engineering philosophy is that it is safer to err on the side of tight tolerancing. This is not necessarily a good approach for a profit making organization.

3. Repeating tolerances from similar previous designs which may have been unrealistic originally.

4. Selecting tolerances from company, vendor or industry design standards which tend to favor tight tolerances. An example is drill size tolerance charts which are intended to promote the sale of new drills. Hole size accuracy begins to creep up on the tolerance limits after drilling just a few holes. The result is increased frequency of drill sharpening and replacement.

5. Tight tolerances are often considered synonymous with good quality or achieving performance. There is usually no correlation.

Unreasonable tolerances placed upon the manufacturing

community have contributed significantly to the rapidly escalating acquisition costs of military hardware within the past 20 years. Producibility design control applies to and benefits one of a kind, low quantity, and mass production operations.

The problem in this writing is to provide specific management strategies for achieving maximum producibility design control in military equipment. Management aspects of a producibility program that are part of the strategic plan include, who has the responsibility for what, where milestones should be placed, why the producibility efforts are required, and how to reach the objectives of producibility design control.

Methodology and Procedures

The system for developing this project began with an assessment of the available literature on producibility. The specific area of a management implementation strategy for producibility principles was promptly identified as an area fundamentally in need of further research, evaluation, and strategy proposal development. The research was conducted through the following means.

Extensive bibliography searches included the use of subject guides to books, Applied Science and Technology Index, and the Research Guide to Periodical Literature. Computerized data base searches including the Defense

Technical Information Center (DTIC) provided additional sources of related subject matter including material from some very obscure journals. Bibliographies from collected data provided further avenues for the research.

Additional insight into the subject was provided through comprehensive discussions with recognized experts in the field including representatives from government, prime contractors, subcontractors, and private industry. Reviews of prime and sub-contractor producibility programs and detailed producibility reports were reviewed in searching for a common denominator. A wide variation in the application of producibility principles was evident, even within different departments of the same company.

Extensive personal experience in the field has provided a foundation for the study as well as motivation to provide a basis for improvement action. Relevant data on producibility as well as specific product producibility improvements are primarily qualitative in nature. Very limited quantitative information is available due to the amount of time and the expense required in determining actual cost differences. Sources of information included but were not limited to:

1. Technical papers presented at professional society meetings.
2. Journals, periodicals and textbooks.
3. Industry guidebooks.

4. Company drafting standards.

5. Master's thesis and doctoral dissertations.

6. MIL-STD-1528, Production Management.

7. DOD Directive 4245.7, Transition from Development to Production.

8. DOD Directive 4245.6, Defense Production Management.

9. DOD Directive 5000.1, Acquisition of Major Defense Systems.

10. MIL-HDBK-727, Military Handbook, Design Guidance for Producibility.

Applicable information was gathered and formulated into a model of the desired theoretical condition to be established as a goal. On site analysis of a Defense Department prime contractor's producibility efforts was utilized in contrast with the theoretical model in development of the management strategy proposal.

Study Limitations

This writing addresses producibility in the acquisition process for the development of military hardware. Minimal comparative reference is made to commercial hardware development due primarily to different environmental factors in areas such as competition, product liability and sources

of funding. Historical development of the need for producibility and the current status will be addressed.

Definition of Terms

Definition of the following specialized terms and acronyms used in this writing are presented to provide a common foundation for the reader.

DIPP. Design Induced Production Problem. Generally a manufacturing problem that could have been avoided by the design agency through engineering drawing requirements. A DIPP occurs when a manufacturing problem can not be resolved through process changes. Included are design requirements that are not within the realm of manufacturing capabilities.

DPEP. Design-PEP. (pronounced dee-pep). The Advanced Production Engineering function of Producibility Engineering and Planning (PEP), that is responsible for producibility design assurance of the Technical Data Package (TDP). Also referred to as producibility measures. See PEP.

Drawing Review. An organized activity providing the opportunity for a structured critical review of drawing requirements and their corresponding function. Drawing reviews should be conducted during each development phase of concept, layout, and detail, including assembly and installation drawings.

Frozen design. A frozen design prohibits changes to the design. Usually occurs just prior to design completion

and when schedule takes precedence.

Hidden costs. Time and money expended that is not directly reflected in the cost of an item. An example is the resolution of disagreements over drawing requirements between manufacturing and inspection. High quality costs also may not be reflected in item prices.

GD&T. Geometric Dimensioning and Tolerancing, the language of both producibility and of engineering. Formally outlined in the American National Standards Institute, ANSI Y14.5 specification, which provides rules for placement of the requirements of the designer onto engineering drawings.

PEP. Producibility Engineering and Planning, the production engineering tasks and production planning measures undertaken to ensure timely and economic transition from the development to the production phase of a program. See DPEP.

Producibility. The relative ease of producing an item or system. This is governed by the characteristics and features of a design that enable economical fabrication, assembly, inspection, and testing, using available production techniques.

PRAM-D. Producibility, Reliability, Availability, Maintainability, and Durability. A program to improve these characteristics by influencing the basic design criteria. This writing adds producibility to the well established RAM-D programs in recognition of the need for design improvements to enhance product producibility during

production.

PRR. Production Readiness Review, a formal design review to determine whether the design is ready for production. Usually conducted after the design has been frozen, a time when changes are actually discouraged.

Source control drawing. A drawing depicting an item that may only be obtained from the sources listed on the drawing.

TDP. Technical Data Package. Documentation including drawings and specifications that constitute a product definition. Drawings control and delineate shape, form, function, and interchangeability of an item. Documentation must be sufficiently defined to permit a competent manufacturer to produce an item without recourse to the design agency.

Chapter II

Review of Literature

Information on the characteristics and various implementation philosophies of producibility as a discipline is available from all branches of the military, a variety of commercial product development industries, and is addressed in one form or another in many free world nations. The common denominator is recognition that the development and acquisition process of military hardware mandates a team design effort with the objective of creating designs having favorable characteristics of producibility. Systematic communication and coordination between product design engineers and manufacturing engineers must begin early in the design process.

Design agencies are accepting their responsibility for creating designs that meet technical performance goals as well as a level of requirements that manufacturing can build to. History has consistently demonstrated the wisdom of this team mixture of expertise. As Roy Rothwell (1984, p.90) points out, an engine manufacturer had expended five years designing a new engine. A two year technical lead over their competition and strong positive market research provided cause to proceed rapidly into full scale production. The design department had functional design

areas that were rigidly compartmentalized. Consequently, the production department had very little input into the engine's development. Only after the design was released to production were the many production difficulties uncovered and the consequence was a two year delay in production. Meanwhile, a competitor entered the market with a similar engine and the initial market lead was lost.

Historical Perspective

As related by Wallis (1969,p.10), the earliest known engineering drawing dates back to about 2400 B.C., and was drawn on a stone tablet. Although engineering drawings have been around since that time, the application of tolerances and the recognition of allowable dimensional variations did not appear until after 1890. The Industrial Revolution and concepts of mass production, interchangeable parts, and multiple manufacturing sources have stimulated universally accepted drawing standards and commonality of interpretation of the written engineering language between engineer, draftsperson, production, inspection, and the product user.

Prior to 1890, the system used for product acceptance was the contract system. Under this system the criteria for accepting an item and the valuation of it's quality was based solely on performance. If the item did what it was supposed to do, it was purchased, otherwise it was returned. The philosophy today is perhaps completely opposite.

Performance is not necessarily the responsibility of the manufacturer, rather, if an item is built to the drawing, and does not do what it is supposed to do, the problem becomes a design problem and is the responsibility of the designer. An item that conforms to it's drawing requirements must be accepted and paid for. This is logical since the manufacturer has fulfilled the contractual obligations.

The reason for a focus on engineering drawings, tolerances, and interpretation of drawing requirements in a study on the implementation of a producibility program is that these drawings are the communication medium between disciplines. Producibility has become an umbrella encompassing the entire development and acquisition process. Producibility is directly related to the engineering drawing which is the common focus of all the various disciplines such as design engineering, production engineering, quality assurance, product assurance, purchasing, project management, and of course the end item user.

Evolution of Producibility

The roots of producibility as a discipline follow the characteristics of production planning and advanced production engineering. By definition, producibility

involves a complete assessment of the total available resources to accomplish the production requirements of a particular design, including the availability of in house and subcontractor resources. Dimensioning and tolerancing decisions are an everyday part of achieving the delicate balance between functional design requirements and manufacturing capabilities.

Creation of producibility characteristics of a product have in the past been strictly limited to the design engineer, who would review functional specifications, develop a concept, create detail drawings, and release the completed design to production. As Pertowski (1980,p.1128) relates, this has been when manufacturing becomes involved. Designs are complete, therefore, only minimal improvements for production efficiency would be permitted.

Special emphasis has been given to producibility in recent years due to rapid increases in procurement costs when production operations begin. Cost escalations higher than they should be. Analysis usually indicates that while the product meets it's functional purpose, the product lacks the characteristics for economic and efficient production.

The two major functions of advanced production engineering were separated in 1973 by the Defense Department. Initial Production Facilities (IPF), which are hardware related items such as tooling and production line setup equipment, was to continue to operate with procurement funds. The other major function which is software oriented

toward drawings and manufacturing processes are production engineering measures, now called producibility and planning. Producibility and Planning is accomplished with Research and Development (R&D) funds. The result is that producibility efforts have had to compete with other R&D efforts for resources. Design engineering problems have usually taken precedence over producibility for funding. Generally, remaining funding for producibility is too little too late.

The necessity and potential benefits of producibility is currently receiving attention from the highest of authority levels. Gilbert Tallar (1984,p.11), a government consultant on producibility, relates the emphatic comments of Commanding General Donald R. Keith, "There are no activities in the weapon system acquisition process that demand greater attention than those directed toward assuring effective transition of developed hardware into efficient production." The importance of producibility analysis and it's place in the design intensive phase is generally recognized today.

Trends

Increasing numbers of industrial firms in both military and commercial business have started formal producibility functions in recent years. The names may be different. Ford Motor Company calls it simultaneous or concurrent engineering ("Ford's Betti",1985). The British

refer to it as makeability. To many others it's simply the concept of upfront designing for production. The complexity of modern design and manufacturing is beyond individual design capabilities and mandates team efforts.

Producibility efforts now endeavor to develop equipment and systems at the lowest cost and the minimum lead times for delivery while not degrading other design specifications such as performance, reliability, and maintainability. Producibility efforts usually have positive effects that enhance these other design characteristics.

Trends are toward creating staff functions with the mission of producibility design assurance. The age old barriers between design and manufacturing do not become any less when manufacturing expertise is placed in the design room. Trade-off decisions occur in reaching compromises. Function takes precedence over producibility in drawing requirement decisions. Producibility changes that occur are manufacturing enhancements that do not degrade function, and last for the production life of the design. The project manager, directed by the customer, has the responsibility for implementing producibility into each program. The frequency of contractual requirements and management commitments are steadily increasing toward the goals of producibility design control throughout the acquisition process.

Literature Review Summary

Producibility as a disciplined design approach has evolved out of a need due to production problems in efficiency, timeliness, productivity, and cost, resulting from design and technology advances and the high levels of complexity in modern equipment acquisition. The need and benefits from producibility have been identified and established by the Department of Defense. The method of application of producibility design control varies throughout industry.

Refinements in the application of producibility during the design intensive phase of product development need to occur in the methodology used for implementing producibility design control. The key to creating production ready, producibility enhanced designs is to keep a constant consideration for production in the beginning and throughout the design process.

Chapter III

Study and Analysis of Data

During the evaluation of various implementation strategies for producibility design inputs, certain strategies stand out as more effective in creating producible designs. Competition differences between military and commercial design development cause their producibility efforts to be treated differently.
The end user in commercial designs is not concerned with the levels of difficulty in manufacturing the product. Commercial designers must by the nature of the competitive factors in their product market, obtain efficient production by designing for high levels of producibility.

Military equipment markets are limited in quantity and often to one customer. Creating producibility enhanced designs require increased time and labor during the design process. Fixed cost design contracts, producibility funding from R&D sources, and schedule constraints, easily place producibility considerations at a lower priority. The military customer literally buys the design and then pays what it takes to build to the design. The commercial customer buys the product and not the design. These

differences are necessary due to the logistics needs of the military, and are not the issue here. Rather, they explain the need for military customer support of producibility design control.

Development Process

Figure 2 (Mediratta,1980,adapted) depicts relative cost versus the design development process, a function of time, for both total systems and individual components. Producibility is a continuous process that can benefit each acquisition phase as well as the total cycle. It is

See Figure 2

important to note that the cost reduction potential as well as the cost to implement the producibility changes, provide the greatest potential for savings if producibility considerations receive early attention. Further, the place that producibility has been implemented historically provides only a portion of the total potential savings that would result if implemented sooner. Delayed implementation results in higher costs to incorporate producibility changes into the design.

Producibility enhanced designs can occur from taking more calendar time in the validation/layout phase and correspondingly less calendar time in the full scale

development/detail phase. Basically, considerations for production, which usually occur during full scale development, are accomplished earlier during the validation phase. This up-front development would cost more on the short term since there are usually several contractor/design concepts in this phase. However, the selection of a particular contractor/design that had the up-front development and production considerations built into the design will provide the long term benefits and will lead to the shortened acquisition cycles that have recently been established as major Department of Defense goals (Thompson,1984,p.18). Concentration on designing for producibility will reduce the need for Production Readiness Reviews which usually occur long after a design has been frozen and just prior to entry into production.

Various levels of drawings are developed during the design process, the first being level 1, prototype drawings, which as a minimum describe sufficient detail to produce the components. Level 2 drawings are intended for low rate production and are usually not created so as to expedite the development process into production. Drawings released for production are generally of the level 3 status, completely delineated and properly formatted. The tendency has been not to emphasize production considerations for level 1 drawings and to incorporate production considerations into level 3 drawings. Two factors block producibility improvements at conversion to level 3. One,

hardware is validated to the level 1 configuration and therefore establishes a functional precedent of the requirements. Any changes lead to questions of the integrity of the validation. Second, requirements that have previously been put on a drawing are treated as sacrosanct. Generally it is to late if we want to make major producibility changes at the level 3 drawing conversion. The difference between these levels of drawings should only be regarded as format or neatness. Dimensions and tolerances must always be evaluated for production at the level 1 stage.

Environmental Principles

As the development of an effective strategy plan for producibility design control was being formulated, certain philosophies evolved which established program management principles. Management must understand the following principles as foundations for a strategic action plan.

First, the design agency often has a tendency of resistance against producibility changes. Producibility requests for design modification to enhance manufacturing are often regarded as challenges to the design engineer's previously established requirements and personal ability to establish those requirements. The producibility function must meet organizational and customer objectives by utilizing limited resources and coping with diverse elements

in environments that often become hostile. The designer frequently believes an item meets producibility criteria as long as it can be produced by some means, which is demonstrated by completion of the prototype. Considerations must include the level of production difficulty required to meet drawing requirements and that drawing changes to improve producibility are mandatory. In some instances judgemental decisions are made favoring design or producibility proposals.

Second, the responsibility for the producibility of the TDP rests completely with the design agency. When releasing designs for production, drawings must be released with requirements that are within manufacturing process capabilities for the desired production quantities. Conversely, manufacturing is not responsible for the producibility design characteristics. Manufacturing is tasked with the planning and procedures necessary for obtaining the drawing requirements. Simply stated, when production problems cannot be resolved through process changes, the problems shift from manufacturing problems to design problems requiring design agency corrective action to the engineering drawings ("You're wrong if",1981,p.53).

Third, the responsibility for demanding formal producibility efforts of equipment developers rests firmly with the government. Producibility program requirements are enforced through the program manager. Since the government is purchasing the product design, the primary benefit of a

producibility program is to the government in assuring a product that is structured for economic production. The goals of producibility are well within the realm of what contractors strive for. However, the reality is that producibility efforts increase development cost and development delays outside of product performance considerations. Consequently, a program without direct lines of authority, strong contractual requirements, and proper funding, may result in a "rubber stamp" approval operation.

Fourth, the discipline of producibility is an assurance function. The product designer is still the designer. Guidance and support in providing manufacturing input and expertise is the role of the producibility engineer. The producibility engineer is also a source of verification to the designer of manufacturing problems and a source of verification to manufacturing of the design needs.

Fifth, engineering drawing signature approval on the original master drawings by representatives of the producibility organization prior to procurement action or production release is mandatory to effect the necessary authority to support the responsibility for producibility assurance (Pertowski,1980,p.1133). Signature authority provides motivation to effect producibility improvements.

Sixth, the criteria for producibility objectives is not cost, rather cost effectiveness. This is a function of time, value and dollars (DOD,1984,pp.1-11). Cost

effectiveness includes such difficult parameters to measure as quality and production efficiency which actually begin with the first stroke of the designer's pencil.

Mr. S.J. Lorber, Director of Product Assurance and Testing, U.S. Army Material Development and Readiness Command, noted at a PEP Conference ("Conferees cite",1983,p.7), that quality and producibility are inseparable. Large quantities of money and effort are spent on achieving and measuring quality in the production facilities. Producibility measures, or what is introduced here as Design Producibility Engineering and Planning, (DPEP), are efforts to place into designs from their very conception the characteristics of quality such that the parameters generated by the designs in dimensioning and tolerancing drawings are within the realm of realistic manufacturing capabilities. Only then can efforts at achieving true product quality be within reach.

These precepts form the basis for the development of a producibility design control program. Understanding the conflicting nature of environmental factors that occur when combining manufacturing and design people is essential. The proper assignment of producibility problem resolution to manufacturing problems or problems that can only be resolved through design changes to the TDP is frequently difficult and addressed by "band-aid" types of corrective action. A producibility group that is neutral and unbiased to manufacturing or design has the ability to direct the ideal solution for long range benefits.

Placement of the Producibility Organization

The group responsible for producibility should be established as a staff function within a matrix organization. As previously stated, the importance of enforcement through the individual program manager necessitates a second reporting relationship. The functional identity provides for economic utilization of expertise and resources when accomplishing task assignments. This reporting structure maintains the linkage between various elements of the organization while the second reporting requirement through the program manager places emphasis upon the specific task responsibilities. This dual reporting relationship provides an optimization of goals and resources (Rowe,1982,pp.236-246).

One specific functional department must be recognized as the representative of the production organization which includes purchased parts, in-house manufacturing, assembly and installation. This producibility organization must have approval and disapproval authority of design data, extensive and continuous feedback with design engineering and the various production facilities, and be staffed with highly competent technical people. The correct structuring of the producibility function will be effective during the concept, validation and full scale development phases, and then be in a position to maintain producibility design control

throughout the production cycle. There are several alternatives to consider for placement of the producibility function within the matrix organization.

1. Do not have a designated functional element of producibility. This approach would leave the attainment of producibility goals to the other functions involved with design development. This is what has existed and historically produced many examples of poor producibility. The concept of not having a designated function is presented here only since that is still a possible approach. Upon agreeing to the need for producibility, the question becomes how much and where to structure the producibility organization to create an effective focal point within the design agency.

2. Structure the producibility function under the product design or systems engineering function. This is the place that has total design responsibility and therefore is best able to incorporate producibility goals into designs. However, this would lead to a conflict of interest in that there would be no system of checks and balances. We have established producibility as an assurance function and as such the reporting chain of command must be seperate from that of the design engineer. This avoids situations compromising the long term benefits of producibility objectives for short term development problems.

3. The producibility function could be structured within the manufacturing operation. This would place the

producibility personnel in a very biased situation that would also negate a system of checks and balances. Further, not all of the design may go to the same manufacturing area since subcontractors may build certain components. The actual manufacturer may not be identified at the early stage of design development. Usually, designs become somewhat unchangeable by the time manufacturing receives them, leaving marginal room for producibility improvements.

4. The producibility function could be structured under the procurement operation. Again, an area that usually becomes involved after the design has become somewhat frozen. This area is not technically cognizant of either the design parameters nor manufacturing capabilities. Placement here is too far from the design activity and would be ineffective.

5. The producibility function could become a completely new function reporting directly to top management and situated within the design agency. Building intergroup linkages will require very determined efforts. This group would be somewhat external to all other functional elements, creating greater obstacles to success. Most development programs are not large enough to support the levels of management for a separate producibility organizational structure.

6. Establish the producibility staff function under the product assurance organization. We have already established that the producibility program as such is an assurance

function. The intergroup linkages exist as well as the system of checks and balances. Producibility will parallel other assurance activities such as reliability, maintainability, quality assurance, and human factors. All are groups which maintain design development support throughout the acquisition process.

Regardless of the actual placement of the producibility function within an organizational matrix, the producibility principles developed here will apply. The achievement of the most beneficial reporting relationship for the organization is also essential for realizing the sought after balance between design requirements and manufacturing capabilities. This group has the authority to accept or reject new or modified designs based upon producibility criteria. The signature approval authority must be a mandate from the program office and top management within the matrix organization toward guaranteeing producibility is within the design routing cycle. The producibility function must interface between design and the various manufacturing sources.

Producibility Program Plan

Establishment of producibility engineers as integral components of the design team working directly with the product engineer and the drafting department is crucial to the successful incorporation of a DPEP plan. No longer can

the design process as shown in figure 3 be tolerated. The high cost escalations that have often occurred when production begins are a logical extension of this one-way communication toward manufacturing. The activity block

See Figure 3

that shows design changes for functional purposes must be expanded by an effort to uncover producibility problems and have those corrections made along with the functional changes.

The DPEP program plan establishes the organizational structure, lines of authority, responsibility, methodologies, objectives, monitoring activities, and design process flow chart. This plan should not be confused with the actual producibility analyses. The plan is prepared by the design developer prior to the concept phase of development in accordance with the contractual request for such a plan. The plan shall outline a program of regular formal and informal producibility design analyses to be conducted on each design element being developed, and the procedures requiring drawing sign off by the DPEP representative. The plan should include detailed procedures, review criteria, and checklists for accomplishing the producibility analyses.

The producibility plan as well as the actual application of producibility design control is not limited

to high production items, but is also applicable to low rate production and even one-of-a-kind manufacturing programs. (Gimigliano,1983,p.25). Various government agencies are discovering the benefits of total cost reduction and increased product quality through DPEP efforts even in low production quantities. Although the anticipated production quantities are important during the producibility analysis, the characteristics of a design that enhance the ability to produce the component are valid for whatever quantity is specified.

Members of the producibility team must be highly capable and well qualified in their field since their task is that of reviewing, improving, and approving the work of other functional elements. The diversity of knowledge required of the producibility engineer spans the fields of production engineering, design engineering, quality assurance, product assurance, materials management (procurement), materials engineering, industrial engineering, and program management. Each of these fields have numerous subfields within them. In production engineering for example, there is material removal, forming, joining (ie. welding), casting, forging, assembly, etc. Since knowledge of all these elements is virtually impossible for any individual to have or to expect to be responsible for, the team review concept is established as an effective tool for producibility analysis. Producibility team members are selected with various areas of expertise

for increased coverage of the designs being reviewed. Ultimately, the DPEP team must earn the respect of both design and manufacturing staffs.

The question of how much effort to put into the producibility review of a drawing is important. A five minute review can probably affirm that a component is capable of being produced. Obviously, an in-depth consideration of the necessary processing operations and process capabilities for building to the design can not be treated lightly. A comprehensive producibility review of a drawing will include design review efforts of several personnel from the various areas of expertise, working as a team, discussing the various drawing requirements, their justification, methods to meet them, and drawing improvement ideas. These reviews must occur at a time when drawing changes for producibility can readily be incorporated. Criticisms are not to be piecemealed, but compiled into composite packages prior to delivery to the designer.

Producibility reviews are one activity that can easily accept increased personnel to actually hasten the review process. The ability to have additional producibility oriented personnel join the drawing review activity should be identified in the DPEP plan, as well as the sources of those people, such as manufacturing or inspection. This degree of flexibility in human resources is good in maintaining an orderly review process and avoiding any bottlenecks in the design process.

Implementation Strategy

ne importance of the drawing sign off authority for DPEP cannot be overstated. Although sign off does not redelegate the responsibility for creating producible designs away from the product engineer, it does provide the necessary authority to the DPEP function, and is a fundamental portion of the strategy for DPEP input to the design process. Figure 4 outlines a systematic procedure for establishing a constant formal system of producibility assurance as an ongoing activity within the design development process. Requiring DPEP as a part of the process is an essential element. Note how the opportunities for feedback and interaction between disciplines are established as part of the drawing development process.

See Figure 4

This flow chart provides two distinct areas for producibility input. The first producibility review stage, which follows the materials engineering evaluation, is accomplished during the design intensive time of the process, often before the total design begins to take shape. This is also a producibility intensive phase and is where sign off occurs after the review criteria has been satisfied and changes incorporated. All engineering

drawings pass through the sign off process. The second stage producibility reviews occur after approval of the design by the project engineer and prior to the formal release of the design. During the producibility sign off review, tradeoff decisions usually occur that permit drawing requirements such as tight tolerances to remain due to the rule that function takes precedence over producibility. The second producibility review can compare actual inspection results of prototype hardware built after the first review with the functional performance of the product. This is used to determine if drawing requirements can be relaxed.

The Pareto principle, which says that a certain small percentage of parts will account for a correspondingly high percentage of the total cost, is used to select specific items to receive further producibility evaluations. These key components will often be large or complex portions of the design. This second influx of producibility design evaluations should include support from the actual manufacturing engineers that will build the hardware. If prototypes have been built, the manufacturing and inspection experience will be utilized in preparing the drawing changes for enhanced producibility. The second stage producibility review will be established as a major milestone of the development program and will provide incentive for approval of design changes to enhance production.

A Production Readiness Review (PRR) is not shown in figure 4 because the up front designing with manufacturing

considerations will significantly reduce or eliminate the need for a formal PRR. Readiness for production has been an intensified ongoing consideration throughout the design and has provided improvements long before the design was frozen. The net effect is that the PRR's of the past have been absorbed into the process. A milestone such as the PRR can still be utilized to identify and rank problem areas, however, the cost and duration of the PRR may now be considerably reduced.

Funding for the DPEP, which is primarily software oriented, is to be used for the producibility design control activities of providing design guidance and manufacturing expertise in an assurance type of role, to provide for the in depth design analysis with regard to manufacturing requirements of the design, and for continued monitoring of the program. Producibility analysis may include the necessary design analysis to prove the changes being requested will maintain product function. It is important to note that redesign efforts due to producibility problems are to be funded from regular development funds and not from the DPEP funding.

Requirements for producibility analysis must extend beyond the drawings that are to be a part of the TDP, and include the preliminary design data such as layouts, sketches, prototype drawings and vendor drawings that may become source control drawings. These documents must also have signature blocks and the requirement for sign off by

the responsible producibility organization. The authority to request changes and negotiate drawing requirements is included in the producibility plan. Sign off must be a prerequisite before any hardware procurement action in order to insure producibility remains in the sequence, to provide impetus for incorporating changes, and to substantiate the government/contractor commitment to designing for producibility.

The design layout is an important building block for producibility considerations, and should be delineated dimensionally as completely as possible. This forces the actual designer who is most cognizant of functional requirements to establish the manufacturing requirements necessary for the design. Also, knowledge of the complete picture is readily available, thereby eliminating guess work or tolerancing details without knowledge of mating parts.

Vendor drawings that are the step before becoming source control drawings are analyzed first for their inherent producibility, and then, more importantly for the interface requirements which they will be dictating for the mating component. Unbalanced interface tolerances can result in higher costs for the user.

Source control drawings have been treated as taboo in recent years due to the potential and actual abuse of cost and schedule resulting from their use. We must realize that without source control drawings many design efforts would be compromised, delayed, or result in development cost

increases. In reality, source control drawings can be of substantial cost, quality, and performance benefits to both government and contractors. Rather than buying the design, the product is purchased. Source control drawings are good. What is bad is the single source control drawing. The single source drawing limits procurement of hardware to only one particular source or company. This is a detriment to the producibility of the TDP. The government has the responsibility for requiring multiple sources on these drawings and not accepting a TDP with single source items except when joint government/contractor formal trade board decisions have approved the use of a single source for a specific item. Multiple sources must be developed prior to production release of the TDP with development funds set aside for such action.

Manufacturing of prototype hardware is a valuable source of producibility information and is indicative of problems that may develop in production. Utilization of prototype data can be achieved by strict conformance to drawing requirements and observance of manufacturing performance in meeting the drawing requirements. In many instances conformance to drawing requirements is given low priority not only on prototype hardware, but through low rate initial production and into full scale production before inspection enforcement reaches strict configuration control levels. This laxity, which expedites the program into production, includes waivers, deviations, and material

review board decisions of "use as is". A false sense of the producibility of the hardware is given. Strict initial conformance means that if hardware built for the prototype can be utilized, then evaluation must be made to determine whether to change the drawing to reflect the actual as built hardware configuration. A bias toward changing the drawing should be implied. Observing results of the manufacturing processes on the prototype hardware provides process engineers with valuable information on what to expect and what process changes may be necessary in preparing for full scale production. Producibility decisions include the selection of the prototype manufacturing source, which should wherever possible, be a potential full scale production source for the item. The additional cost and time in utilizing a production source for prototype needs can be offset by the information provided that is representative of what can be expected of the manufacturing process.

A formal plan for producibility improvement of in production components should be established. This task can be accomplished by combining a Producibility improvement effort with the well established Reliability, Availability, Maintainability, and Durability (RAM-D) programs to create the new acronym of PRAM-D. This will provide for manufacturing productivity improvements through a formal means of producibility improvements to released TDP's.

Action Plan

The procedure for implementing strategic management of producibility in military hardware designs require specific actions from three areas, government, industry, and education. Government actions are necessary for achieving the long term benefits of producibility design control in all hardware designs and throughout their entire acquisition and support life cycles. Industry actions are essential to meet producibility design objectives concurrent with ongoing design development. Actions specified for educational institutions provide for long range improvements in capacity of new college graduates to design for producibility.

Government Action Items:

1. Establishment of a Producibility Branch within the military for the purpose of directing, monitoring, and funding contractor and sub-contractor producibility efforts. The branch may be within the production area. However, emphasis must be placed on producibility in relation to the TDP and initial design phases. This will create a healthy government-contractor producibility counterpart arrangement.

2. Contractual requirements for producibility design control must apply to all design efforts in order to eliminate the potential of having similar design efforts within a contractor where some have and some do not have producibility requirements. Producibility being a cost

effectiveness function, is not a place to reduce activity due to funding limitations. The objectives apply whether anticipated production quantities are one or several thousand.

3. Government acceptance of designs should not occur until after both technical performance and producibility criteria have been satisfied. Waivers and deviations are indicators of a design that was not ready for production.

4. Government agencies must be more tolerant of producibility changes to released designs. The long term benefit is strictly to the government in cost reduction of the hidden costs associated with the producibility problems of the product. Producibility changes are often categorized as "nice to have" or as "product improvements" which place the changes into low priority or avoidable classifications. Without producibility changes the production process will remain a costly stranglehold indefinitely. Some cost differences in implementing these changes are to be expected. Note that generally the manufacturing process will not be altered, rather, the control or design limits are increased to agree with the process capabilities. A tooling or gaging cost may be required, however, the long term benefit to the government is still accrued.

5. During the early stages of production there must be a high degree of adherence to drawing requirements through comprehensive inspection and physical configuration audits. Non-conformance must receive corrective action through

process improvements or drawing changes. This adherence and corrective action must be mandated from the government. The cost up front will be replaced many times over the production run.

6. Government developed design guides must be expanded to include recommendations for actual dimensional and tolerance data for mating part assemblies in categories of normal and close tolerance ranges. This data should be established on statistically obtaining a minimum of 95% acceptance within the ranges of normal manufacturing capabilities.

7. A producibility impact review of Military Standard (MS) components should be tasked for evaluating their effect on mating component interface requirements. MS parts are used by designers whenever possible. An example of a problem area is electrical receptacles which when used in a fixed fastener interface, require extremely restrictive manufacturing tolerances in some cases of the magnitude of .001 inch true position. There appears to be substantial cost savings potential in simple design changes to MS parts that can improve the producibility on interface requirements of mating components.

8. Government specifications should be changed such that a drawing requiring the specification would also have to identify the applicable sections. Current practice is is to state on the drawing which sections are not applicable. Generally, this tailoring of specifications is

sporadic, yielding the costly application of unnecessary requirements.

9. A profit incentive program must be developed to reward contractors that develop designs yielding minimum production problems. Higher profit percentages should be granted in operations where minimum waivers, deviations, and MRB activity occur than in operations plagued by high quality costs and production inefficiencies caused due to design induced production problems.

Contractor Action Items:

1. Contractors must require some minimum level of manufacturing experience of their product designers.

2. Product designers must be intimately involved with the manufacturing of their components, with special emphasis over prototype manufacturing and inspection problems. Acceptable discrepancies that occur in preproduction operations must be reflected as acceptable in the production drawings.

3. Job rotation programs between design engineers and manufacturing personnel should be encouraged. The rotation must provide the design engineer with hands on experience in manufacturing and inspection operations. Manufacturing personnel will be involved in establishing drawing requirements and making the associated decisions. These efforts will increase communication and provide insight into the work environment of their counterpart.

4. Contractors should emphasize within their operations

the creation of zero defect engineering drawings with respect to producibility criteria. Contractor management must be fully supportive of producibility efforts.

5. Contractor management must maintain the producibility functional activity within the design process and assign formal routing for documentation approval of all TDP and developmental documents such as layouts and sketches, prior to any procurement activity.

Educational Institution Action Items:

1. Mechanical and Electrical engineering degree programs must devote a mandatory course of instruction on the engineering language of Geometric Dimensioning and Tolerancing (GD&T). Educational institutions are extremely inadequate in curriculum emphasis on GD&T and far below the level of training provided that industry perceives is being taught (Vrajich,1983,p.94).

2. Universities must include in their engineering course work studies that relate product function to dimensions, tolerances, and manufacturing capabilities.

3. A course generally covering various manufacturing processes should be mandatory in the engineering degree programs so as to provide a foundation of knowledge to the graduating engineer about how components are built.

Chapter IV

Summary, Conclusions, and Recommendations

Introduction

The purpose of this study was to develop and present a strategy for implementing a management program of producibility design control that would effect a smooth and cost efficient transition from design development to production of military equipment. The necessity for such a study is derived from current problems associated with massive cost escalations when products enter production. These unanticipated cost escalations occur primarily due to a lack of the necessary characteristics that permit a capability of achieving the proper quality and production efficiencies.

The strategy evolved through influences from private sector information, Department of Defense information, and observance of prime and subcontractor hardware development. Actual experience of the impact of TDP requirements on production operations provided additional insight into the problem.

Summary

Manufacturing uses, as a general rule, make every effort to achieve the requirements requested from the documents. However, when a production problem necessitates corrective action through design changes, considerable expenditures of time and money have occurred through manufacturing attempts at reaching those requirements. Early and constant team work between product design personnel and producibility engineers will avert these costly problems.

Producibility can become a self-fulfilling prophecy due to it's presence on the design team, which creates a constant awareness of manufacturing considerations on the minds of each design team member. Producibility efforts solve production problems before they surface. If producibility goals are accomplished one may never be conscious of the benefits derived, the cost avoided, or of the actual producibility efforts. Producibility levels of various military equipment are in themselves a strategic weapon of increased ability to provide the field with equipment in a timely manner.

The fact that the military buys the design and then pays what is necessary to build to the design, provides the reason for government direction and enforcement of producibility design control. Historically, product

acceptance criteria was primarily performance, whereas today the criteria is conformance to drawing requirements which is different and much more restrictive of manufacturing. The design agency has complete responsibility for the producibility of their designs. The government has complete responsibility for requiring that design development includes high levels of producibility in the equipment designed.

Producibility as a discipline within an organization is an assurance function as part of the design team. The product designer and related drafting personnel are tasked with the objective of including the characteristics of producibility in their designs. Signature approval of drawings by the producibility discipline is a mandatory requirement. Producibility objectives are not cost, but rather cost effectiveness. The producibility organization should be placed in a position where design input is readily accessible and authority is received through both top management and the individual program manager.

A producibility program plan must be established that details the organizational structure, lines of authority, responsibility, methods, objectives, and design process flow. All development programs must include producibility efforts. Even one of a kind projects receive substantial benefits. The producibility function must be staffed with highly capable and well qualified personnel in their field. Rubber stamp drawing approval must be avoided through

comprehensive multi-person producibility reviews and a dedicated effort at design changes for producibility. Key components should receive two producibility reviews, one before prototype build, the other after results of the prototype are complete and before production planning begins. Nonconformance to drawing requirements of prototype and initial production equipment must be rigidly measured and receive corrective action through drawing changes when non-conformance has yielded acceptable performance.

Conclusions

The research and information presented in this study have yielded the following conclusions.

Primary benefits of producibility enhanced designs and producibility changes are to the military. Defense contractors cannot be expected to voluntarily initiate producibility improvements as long as profit opportunity is cost based because producibility improvements reduce both product and quality costs.

The military must be the initiator of producibility requirements and must establish a funding base apart from the development base for each program. Profit incentives are needed that reward contractors for designs that create less problems in production.

Producibility design control is an assurance function that provides design guidance and has authority to reject

designs based upon producibility criteria. Redesign efforts due to producibility problems are funded from design funds and not producibility funds.

A synergistic effect is obtained by combining designers with manufacturing personnel in the design environment. This is a fundamental precept of the strategic producibility plan. Formal document routing paths must include the producibility function.

Design changes for producibility improvements must be favorably received by design and government personnel. Short term concerns are overwhelmed by long term benefits and should be treated as such.

Funding for producibility early in the development process is seed money for the long term. Pay a little up front or pay many times more later. Cost implications are graphically shown in figure 5. Note that the cost delta at production continues on for the entire production life. Maximum producibility can not be reached unless it is

See Figure 5

considered prior to commencing production. The cost savings potential of producibility efforts are greatest, and the cost to incorporate producibility improvements is least, the earlier they are applied in the development process.

Recommendations

On the basis of the findings and conclusions of this study, the following recommendations are presented.

1. The Department of Defense should establish a producibility branch at each command responsible for development of military systems. This branch will oversee contractor producibility efforts and the government interest in TDP development with an eye toward cost effectiveness.

2. Government acceptance of TDP's should not occur until after the production characteristics of the system have been proven. Strict conformance to drawing requirements with drawing changes where applicable, must occur with the prototypes and the first production units.

3. Contractors must accept their responsibility and take action toward designing for producibility.

4. Educational institutions need to train their students in the area of designing for producibility.

5. Future studies should be undertaken to improve the profit situation from cost based to cost effectiveness based.

Study Contribution

The intent of this study is to improve the development system such that product designs arrive at manufacturing with characteristics permitting efficient production. Producible designs reduce significantly the high cost escalations that otherwise occur when production begins.

Hidden costs of quality efforts, schedule delays, and production inefficiencies, due to poor producibility will be reduced. Producibility as a strategic weapon has the effect of preparation for production escalations due to industrial mobilizations. Use of the concepts developed here will provide an optimization of cost, schedule, and quality.

Figures

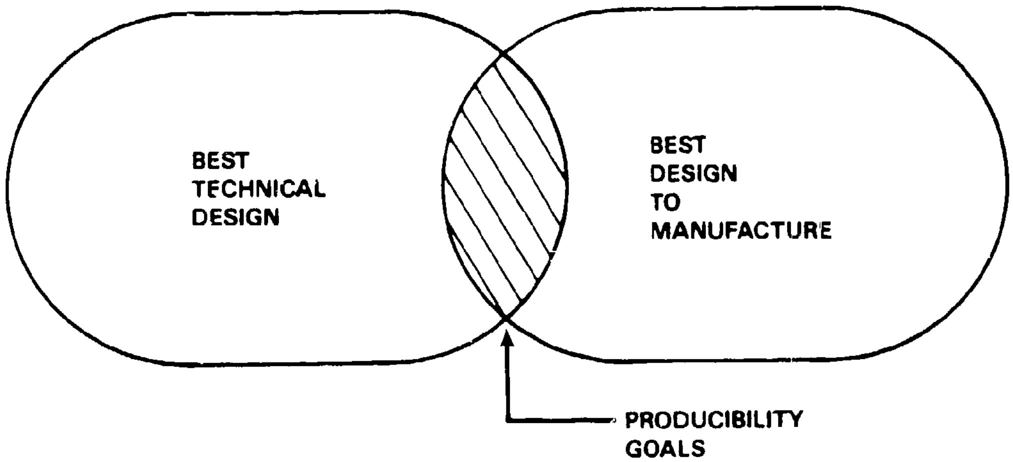
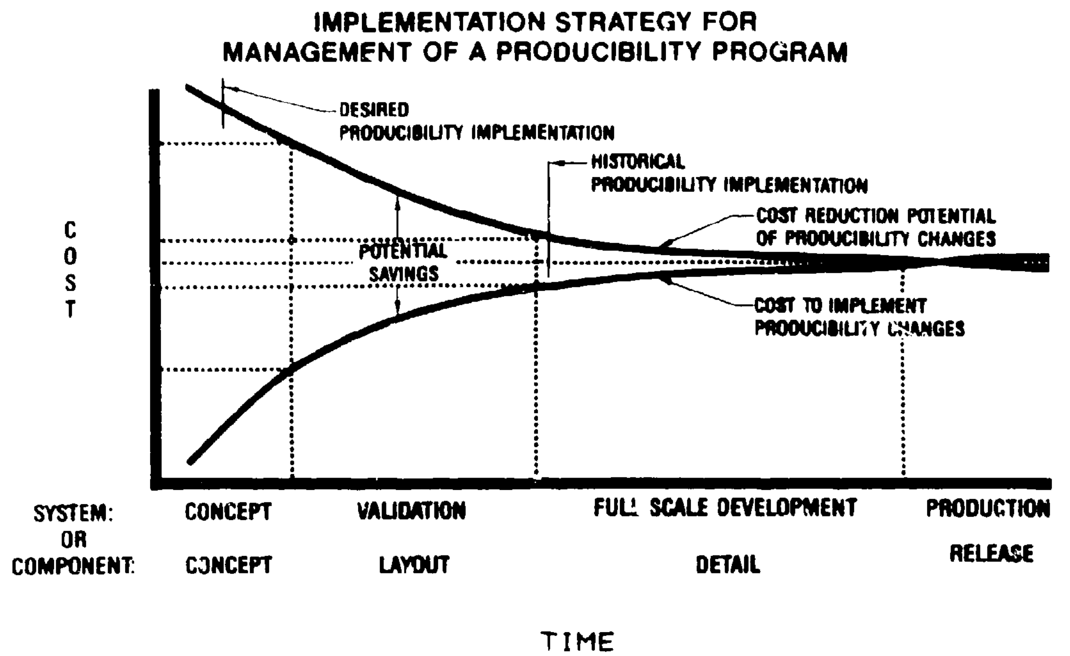

BEST
TECHNICAL
DESIGN
BEST
DESIGN
TO
MANUFACTURE
PRODUCIBILITY
GOALS

Figure 1



(Mediratta, 1980, adapted)

Figure 2

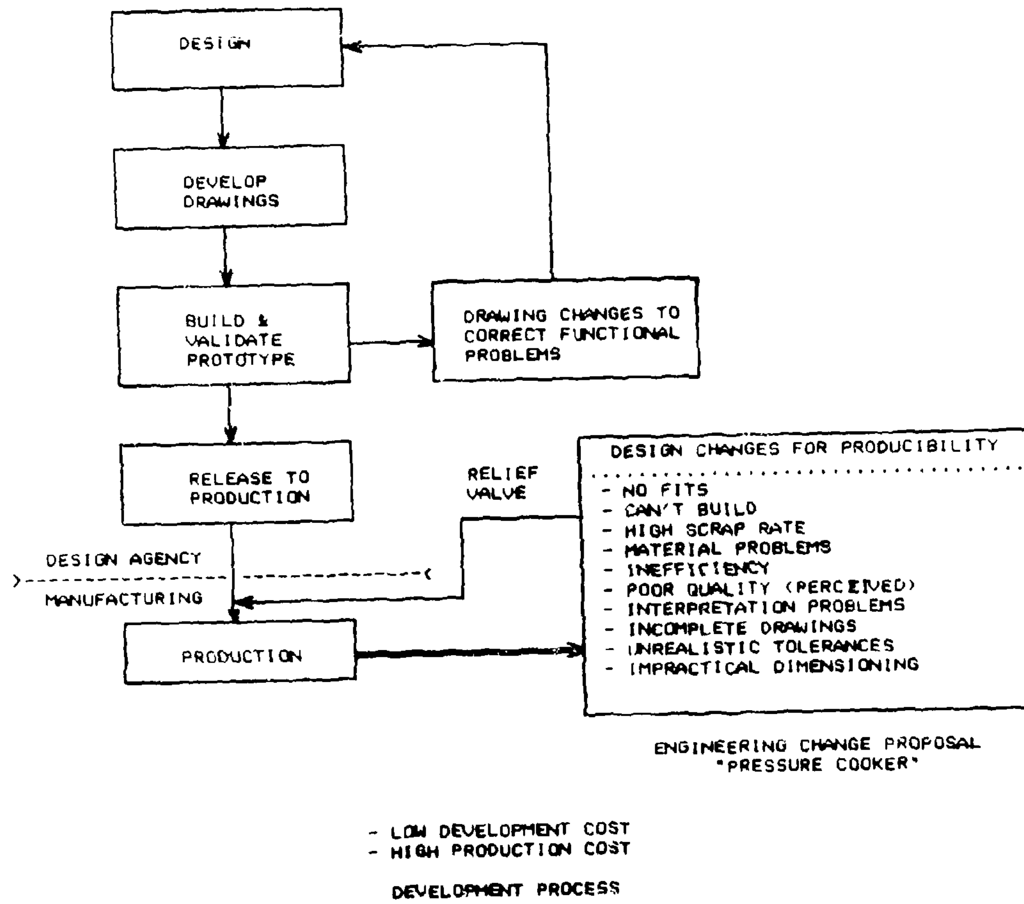
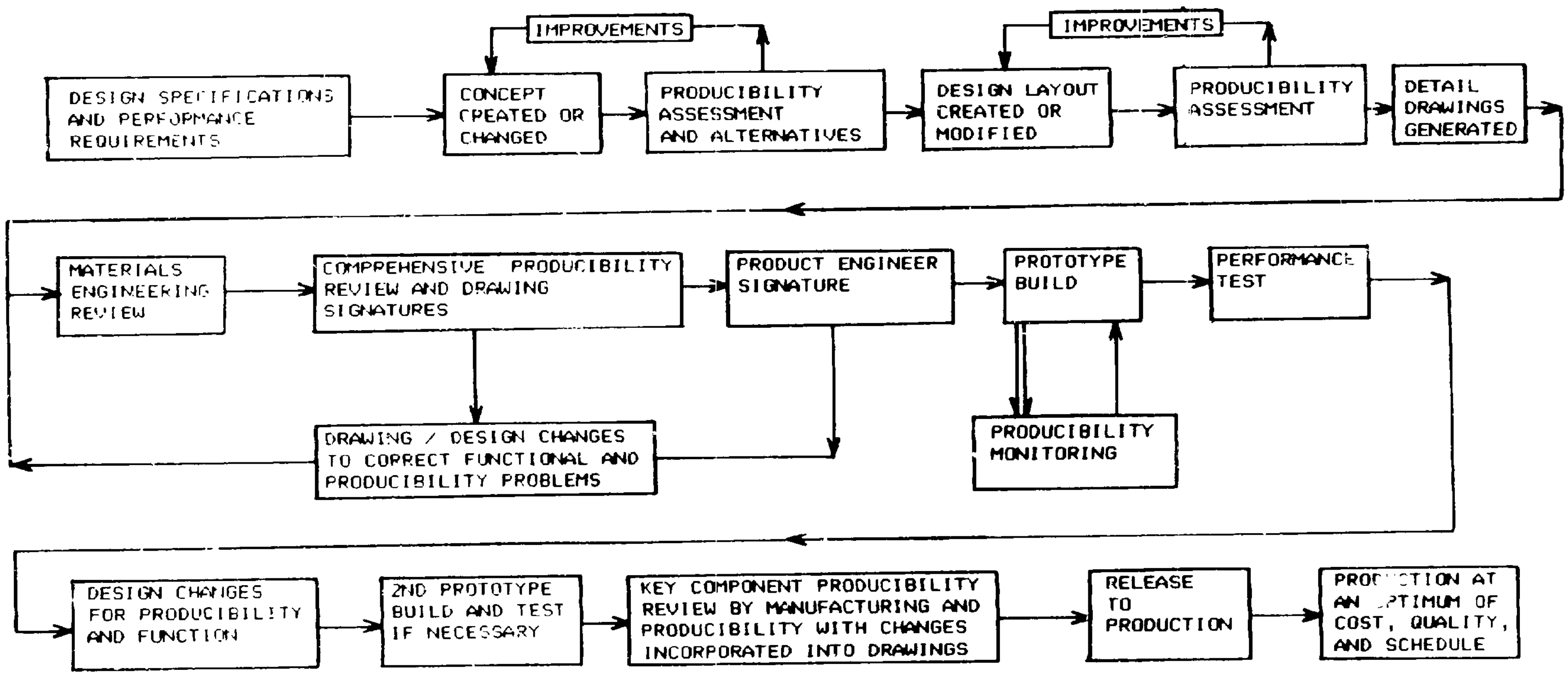
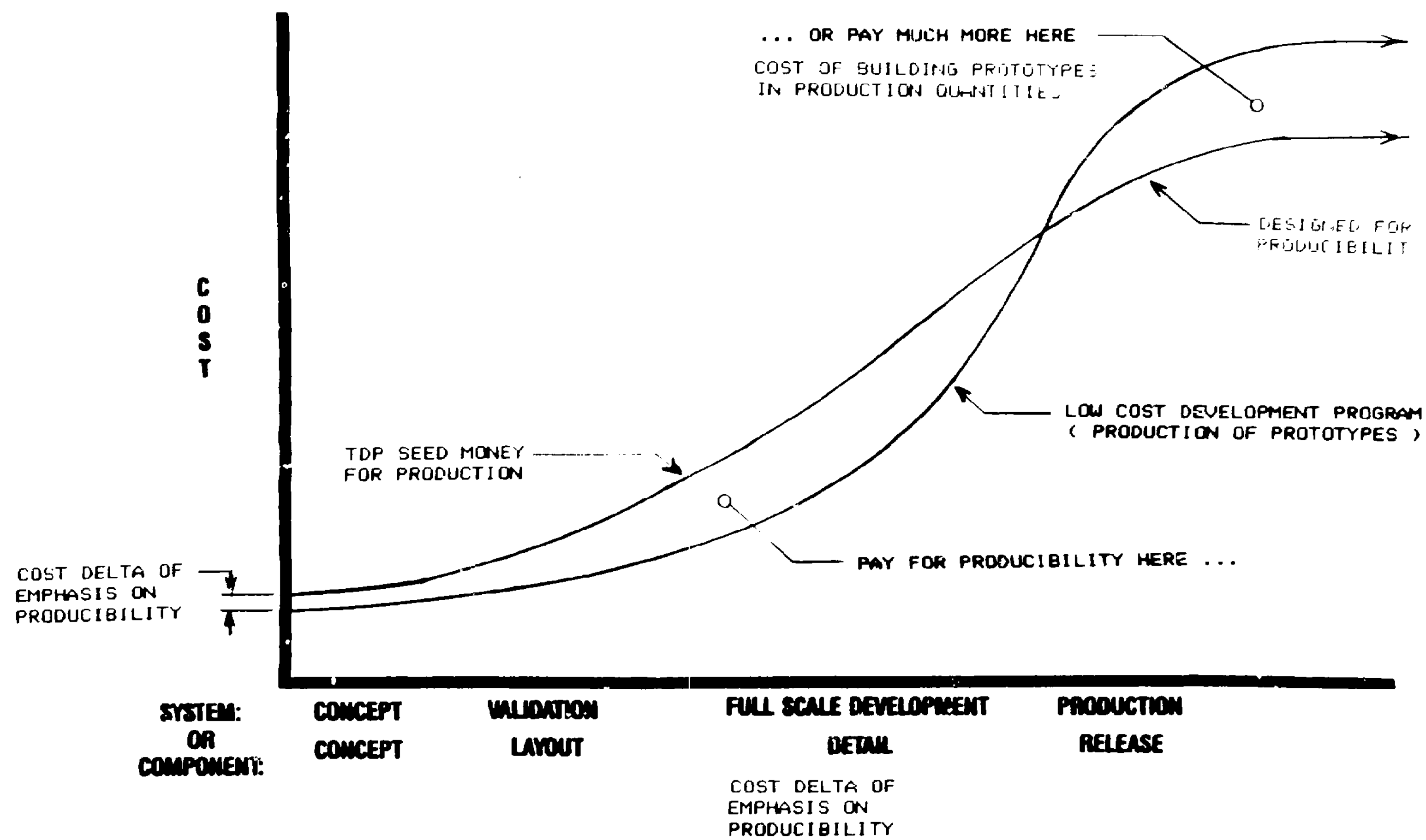

DESIGN
DEVELOP DRAWINGS
BUILD & VALIDATE PROTOTYPE
DRAWING CHANGES TO CORRECT FUNCTIONAL PROBLEMS
RELEASE TO PRODUCTION
RELIEF VALVE
DESIGN CHANGES FOR PRODUCIBILITY
- NO FITS
- CAN'T BUILD
- HIGH SCRAP RATE
- MATERIAL PROBLEMS
- INEFFICIENCY
- POOR QUALITY (PERCEIVED)
- INTERPRETATION PROBLEMS
- INCOMPLETE DRAWINGS
- UNREALISTIC TOLERANCES
- IMPRACTICAL DIMENSIONING
DESIGN AGENCY
MANUFACTURING
PRODUCTION
ENGINEERING CHANGE PROPOSAL
"PRESSURE COOKER"
- LOW DEVELOPMENT COST
- HIGH PRODUCTION COST
DEVELOPMENT PROCESS

Figure 3



IMPROVED DEVELOPMENT PROCESS

Figure 4



... OR PAY MUCH MORE HERE
COST OF BUILDING PROTOTYPES
IN PRODUCTION QUANTITIES
DESIGNED FOR
PRODUCIBILIT
C O S T
LOW COST DEVELOPMENT PROGRAM
(PRODUCTION OF PROTOTYPES)
TDP SEED MONEY
FOR PRODUCTION
PAY FOR PRODUCIBILITY HERE ...
COST DELTA OF
EMPHASIS ON
PRODUCIBILITY
SYSTEM:
OR
COMPONENT:
CONCEPT
CONCEPT
VALIDATION
LAYOUT
FULL SCALE DEVELOPMENT
DETAIL
PRODUCTION
RELEASE
COST DELTA OF
EMPHASIS ON
PRODUCIBILITY

Figure 5

Cited References

Conferees cite importance of producibility engineering. (1983, July-August). Army Research, Development & Acquisition Magazine, pp. 5-7.

Department of Defense. (1984). Military Handbook Design Guidance for Producibility, (DOD Publication No. MIL-HDBK-727). Washington, DC: Author.

Ford's Betti pushes for end to segmented approach to engineering. (1985, February 15). SAE Update, p.4.

Gimigliano, R.F. (1983, January-February). Producibility, the road to increased productivity. RCA Engineer, pp. 25-28.

Hillyard, R.C. & Braid, I.C. (1978, V12N3). Characterizing Non-Ideal Shapes in Terms of Dimensions and Tolerances. Computer Graphics, pp. 234-238.

Leaman, J.M. (1983). Design considerations in the selection of engineering tolerances. In Roth, E., Gaging practical design and application, (pp. 50-76). Dearborn, MI:SME.

Mediratta, S. P. & Dreher, J. F. (1980). Producibility engineering at ASD. IEEE Proceedings, CH1554-1/80/0000, pp. 1116-1127.

Pertowski, T. (1980). Organization and implementation of producibility reviews. IEEE proceedings, CH1554-1/80/0000, pp. 1128-1134.

Rothwell, R. & Gardiner, P. (1984,June). Design and Competition in Engineering. Long Range Planning, pp. 78-91.

Rowe, A. J., Mason, R. O., & Dickel, K. (1982). Strategic Management & Business Policy. Reading, MA: Addison-Wesley.

Tallar, G. J. (1984, March-April). A key for successful transitioning to production. Army Research, Development & Acquisition Magazine, pp. 11-13.

Thompson, Gen. R.H. (1984, November-December). AMC Commanding General Discusses Key Concerns. Army Research, Development & Acquisition Magazine, pp. 18-20.

Vrajich, N. (1983). Geometric Dimensioning and Tolerancing of Engineering Drawings In Post Secondary Programs. Unpublished doctoral dissertation, Colorado State University.

Wallis, C.R. (1969). Positional and form tolerancing: background, present status, and educational implications. Unpublished doctoral dissertation, Arizona State University.

You're wrong if you think producibility is a methods problem. (1981, October). Production Engineering, V28 N10, pp.50-53.

Additional References

Beer, M. (1980). Organization Change and Development a Systems View. Glenview, IL: Scott, Foresman and Company.

Besterfield, D. H. (1979). Quality Control. Englewood Cliffs, NJ: Prentice-Hall.

Boileau, O. C. (1984,August). Improving quality and productivity at General Dynamics. Quality Progress, pp. 16-20.

Chase, R. B., & Aquilano, N. J. (1981). Production and Operations Management (3rd ed.). Homewood, IL: Irwin.

Gimigliano, R. F. (1983, July 4). Producibility - key to cost effective high-tech manufacture. Design News, pp. 30-37.

Hackman, J. R., Lawler, E.E., & Porter, L. W. (1983). Perspectives on Behavior in Organizations (2nd ed.). New York: McGraw-Hill.

Hodge, B. J. & Anthony, W. P. (1984). Organization Theory (2nd ed.). Newton, MA: Allyn and Bacon.

Howell, V. W. (1982). Are producibility and productivity correlated? (Report no. AD82-153). Dearborn, MI: Society of Manufacturing Engineers.

Irving, R. P. (1983, August 1). Quality in design that's where it all starts. Iron Age, pp. 33-40.

Kunz, W. N. (1978). Modern Corporate Management. Englewood Cliffs, NJ: Prentice-Hall.

Levy, S. J. (1974). Applied Geometric Tolerancing. Beverly, MA: TAD Products.

Light, H. L. (1984, March-April). Recent issues and policies concerning Quality Assurance. Army Research, Development, & Acquisition Magazine, pp. 9-10.

Mancuso, C.C. & Lucie, J.C. (1978, April). Cost effectiveness through producibility design control. Naval Engineers Journal,pp. 49-59

Mayben, J. E. (1983, January). Quality precepts: New profits from the modern QA program. Quality Progress, pp. 24-29.

Mundel, A. B. (1982). Quality and Productivity (Report no. IQ82-370). Dearborn, MI: Society of Manufacturing Engineers.

Producibility Language References

Christenson, R. J. & Sautter, E. E. (1971). Geometric Tolerancing and Symbols Learning Guide. MI: Mechanical Engineering Department, General Motors Institute.

Dimensioning and Tolerancing ANSI Y14.5M-1982 (1983). New York: American Society of Mechanical Engineers.

Foster, L. W. (1982). Modern Geometric Dimensioning and Tolerancing with Workbook Section (2nd ed.). Ft. Washington, MD: National Tooling and Machining Association.

Foster, L. W. (1983). A Workbook for Geometric Dimensioning and Tolerancing application per ANSI Y14.4M-1982 and Geometrics II. Minneapolis, Mn: Author.

Foster, L. W. (1983). Geo-Metrics II The Application of Geometric Tolerancing Techniques (rev. ed.). Reading, MA: Addison-Wesley.

FMC Ordnance Division. (1981). Geometric Dimensioning and Tolerancing Manual (rev. ed.). San Jose, CA: Author.

Hill, R. & Jensen, C. H. (1976). Modern Engineering Tolerancing. Toronto: McGraw-Hill Ryerson Limited. ISBN 0-07-082326-X

International Organization for Standardization. (1971). Technical drawings tolerances of form and of position. (R 1101, R 1660 & R 1661, Parts I, II, III, & IV). Author.

International Organization for Standardization. (1981). Technical drawings - geometric tolerancing - datums and datum systems for geometrical tolerances. (Report no. 5459). Author.

Levy, S. J. (1974). Applied Geometric Tolerancing. Beverly, MA: TAD Products.

Madsen, D. A. (1984). Geometric Dimensioning and Tolerancing. South Holland, IL: Goodheart-Wilcox.

Whitmore, G. & Swarthout, J. (1984) Geometric Dimensioning and Tolerancing Simplified. Beverly, MA: TAD Products.

Yuen, A. (1973). Geometrical and Positional Tolerancing in conformance with ANSI Y14.5-1973. Santa Ana, CA: Global Engineering Documents.

Copyright Permission Letters

March 7, 1985

Institute of Electrical and Electronics Engineers, Inc.
(IEEE)
345 East 47 th Street
New York, New York 10017

As a graduate student at Central Michigan University, I am engaged in research on the subject of implementation strategies for management of producibility programs.

In my research of the subject I found very helpful your writing, "Producibility Engineering at ASD", published by IEEE in 1980, reference CH1554-5-1/0000-1116. I would like your permission to copy with minor modifications, figure one, page 1116, on Dollars versus the acquisition process.

Your permission for adapting this information from your publication will be greatfully acknowledged in my thesis and any possible follow on journal articles or presentations.

Sincerely,

Randy S. Dawley

Randy S. Dawley, Researcher
Central Michigan University
C/O 7414 Hartel
Westland, Michigan 48185

/app

March 7, 1985

S. Paul Mediratta
Dr. John F. Dreher
Aeronautical Systems Division
Wright-Patterson AFB
Ohio 45423

Dear Sirs,

As a graduate student at Central Michigan University, I am engaged in research on the subject of implementation strategies for management of producibility pr grams.

In my research of the subject I found very helpful your writing, "Producibility Engineering at ASD", published by IEEE in 1980, reference CH1554-5-1/0000-1116. I would like your permission to copy with minor modifications, figure one, page 1116, on Dollars versus the acquisition process.

Your permission for adapting this information from your publication will be greatfully acknowledged in my thesis and any possible follow on journal articles or presentations.

Sincerely,

Randy S. Dawley

Randy S. Dawley, Researcher
Central Michigan University
C/O 7414 Hartel
Westland, Michigan 48185

/app

IEEE THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC
345 EAST 47TH STREET NEW YORK N Y 10017 U S A TELEX 236411

March 13, 1985

DIRECT NUMBER (212) 705-7364

Mr. Randy S. Dawley
Researcher
Central Michigan University
c/o 7414 Hartel
Westland, MI 48185

Dear Mr. Dawley:

In response to your March 7 letter, we are happy to grant you permission to adapt/reprint one IEEE copyrighted figure in your forthcoming thesis on "Implementation Strategies for Management of Producibility Programs."

Since you are adapting the illustration we require that you first obtain the (senior) author's approval before you consider our permission final. In addition we require that you give full credit to the source (author, paper and publication) and that the IEEE copyright line (© 1980 IEEE) appears prominently with your reference to the adapted figure.

Sincerely yours,

Barbara Howley

Barbara Howley, Administrator
Copyrights and Permissions

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

25 March 1985

Mr Randy S. Dawley, Researcher
Central Michigan University
C/O 7414 Hartel
Westland, Michigan 48185

Dear Mr. Dawley,

Reference your letter dated 7 March 1985 requesting permission to use some material from my paper on the subject "Producibility Engineering at ASD". It gives me great pleasure to learn that you have selected to use the material from the referenced paper. You have full permission to adapt any part of the subject paper. I have co-ordinated with Dr Dreher.

Would it be possible to send us a copy of your thesis? We, here at ASD, are very much interested in the implementation of producibility programs and would certainly appreciate if you keep us informed on the results of your research. Hoping to hear from you.

Sincerely,

SP Mediratta

S. PAUL MEDIRATTA
Chief, Implementation &
Validation Branch
Systems Integrity &
Supportability Division
Directorate of Systems Engineering

Autobiography

Randy S. Dawley is Engineering Supervisor of the Producibility Engineering department at Land Systems Division of the General Dynamics Corporation. He has provided producibility design guidance during the development of the M1A1 Abrams series main battle tank programs. He has over 15 years of manufacturing and design experience in precision machined parts in both military and commercial markets including armored vehicle, aircraft, missle, spacecraft, and automotive applications.

Mr. Dawley, who is a registered Professional Engineer in the State of Michigan, has a Bachelor of Science degree in Mechanical Engineering, BSME, from Lawrence Institute of Technology, and is pursuing graduate studies at Central Michigan University toward a Master of Science degree in Administration, MSA.